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Climatology in long-range transport of Asian dust: Taklamakan versus Gobi deserts

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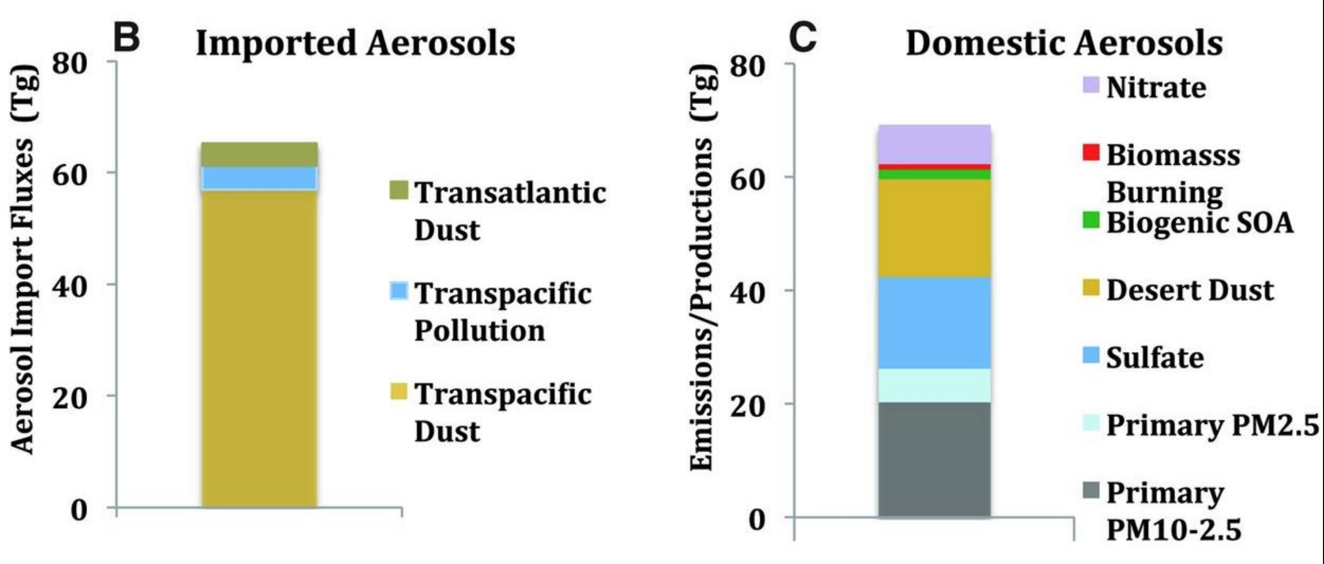
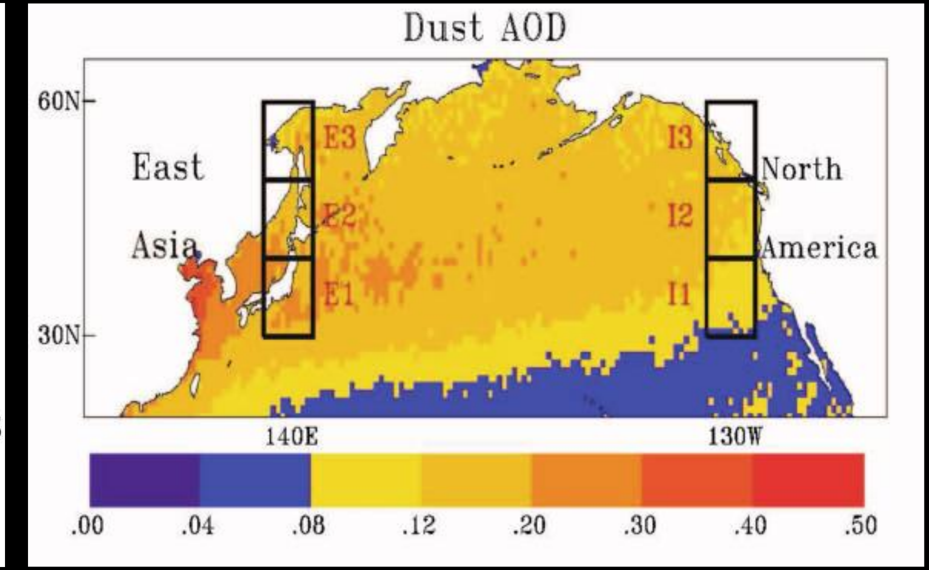
Background

The trans-Pacific dust transport contributes to the total dust burden across the western North America, reported by various observational and modeling studies (e.g., Creamean et al., 2014; Fairlie et al., 2007; Fischer et al., 2009; Kavouras et al., 2009; VanCuren & Cahill, 2002; Zhao et al., 2006).

Satellite-based estimates suggest the trans-Pacific transported dust dominates over local dust sources in North America (Yu et al. 2012)





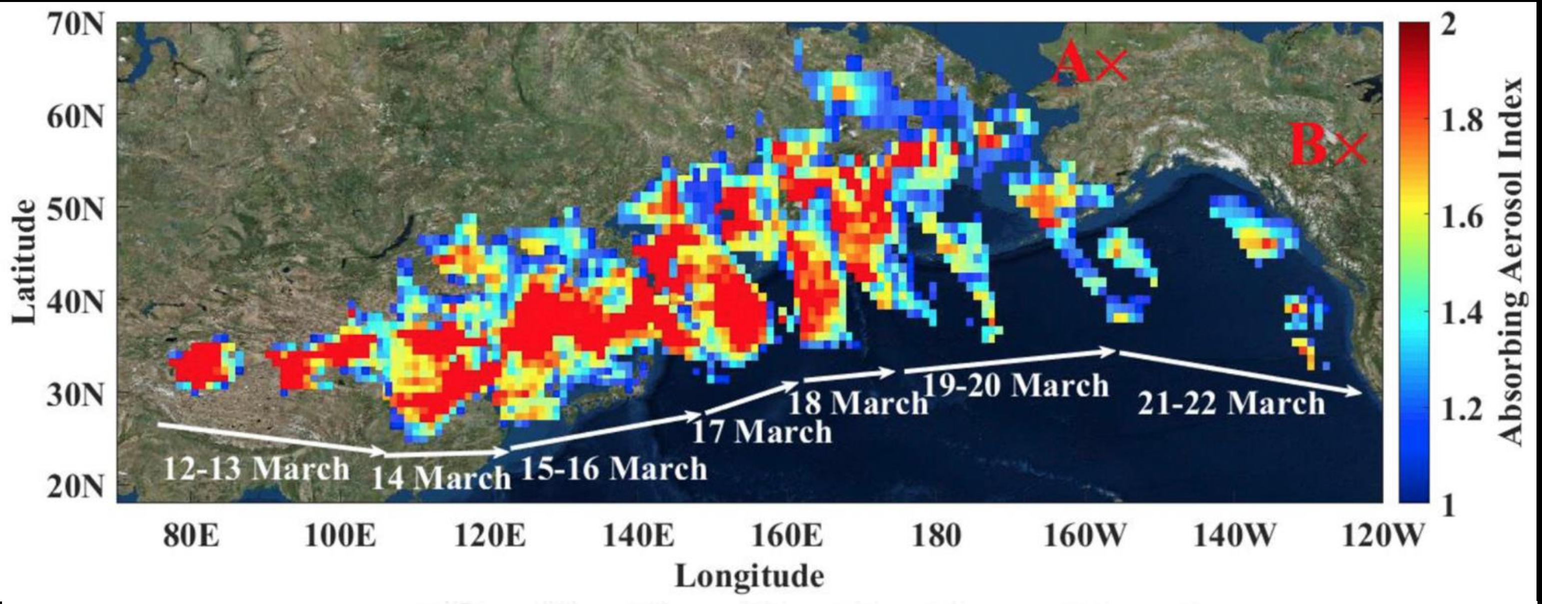
Taklamakan vs Gobi dust sources

The Taklamakan is the largest desert in China and the second largest sand-shifting desert in the world.

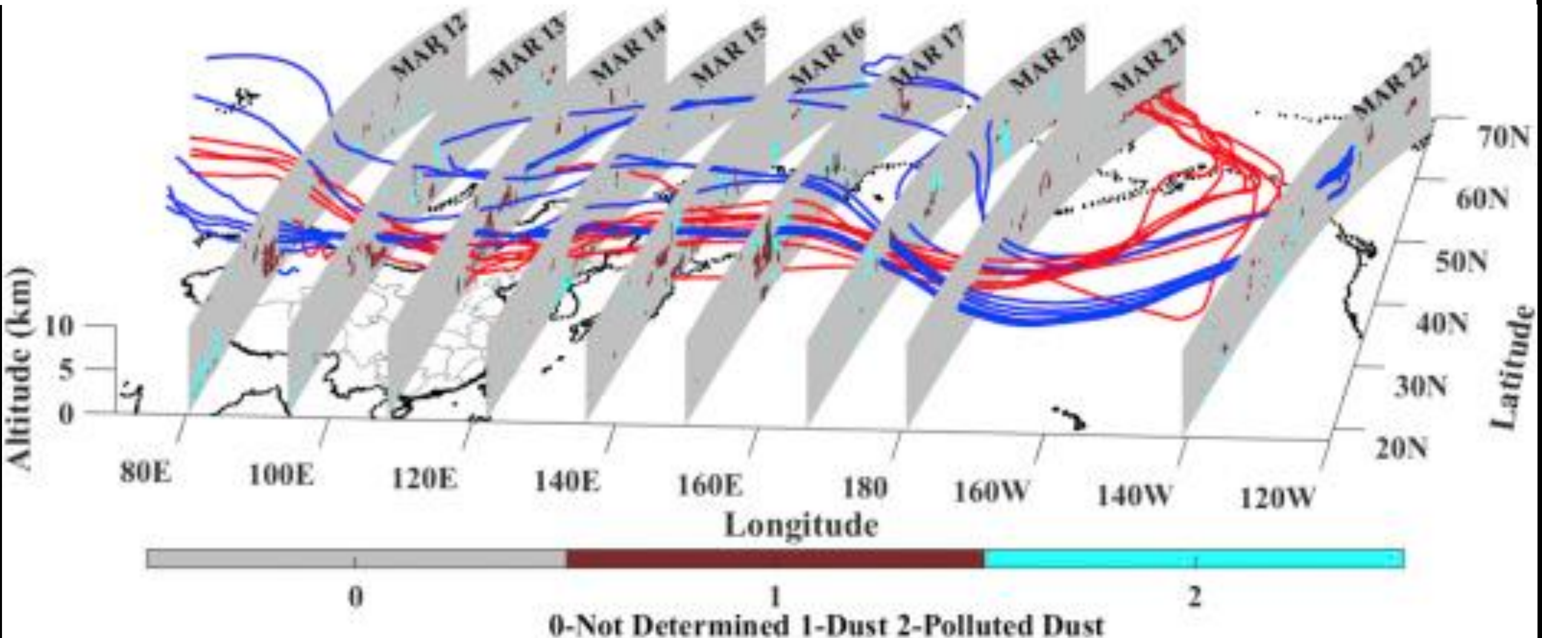
The Central Gobi Desert is the fifth largest desert in the world. It is not as sandy as typical deserts with mostly bare rocks making up the desert floor.

Based on WRF-Chem, Chen et al. (2017) concluded relatively high dust emission but low potential for long-range transport from the Taklamakan desert, due to topography and surface wind climatology.

Case study: March, 2015



OMI/Aura derived absorbing aerosol index showing the temporal evolution of dust episode originating from northeastern Asia.



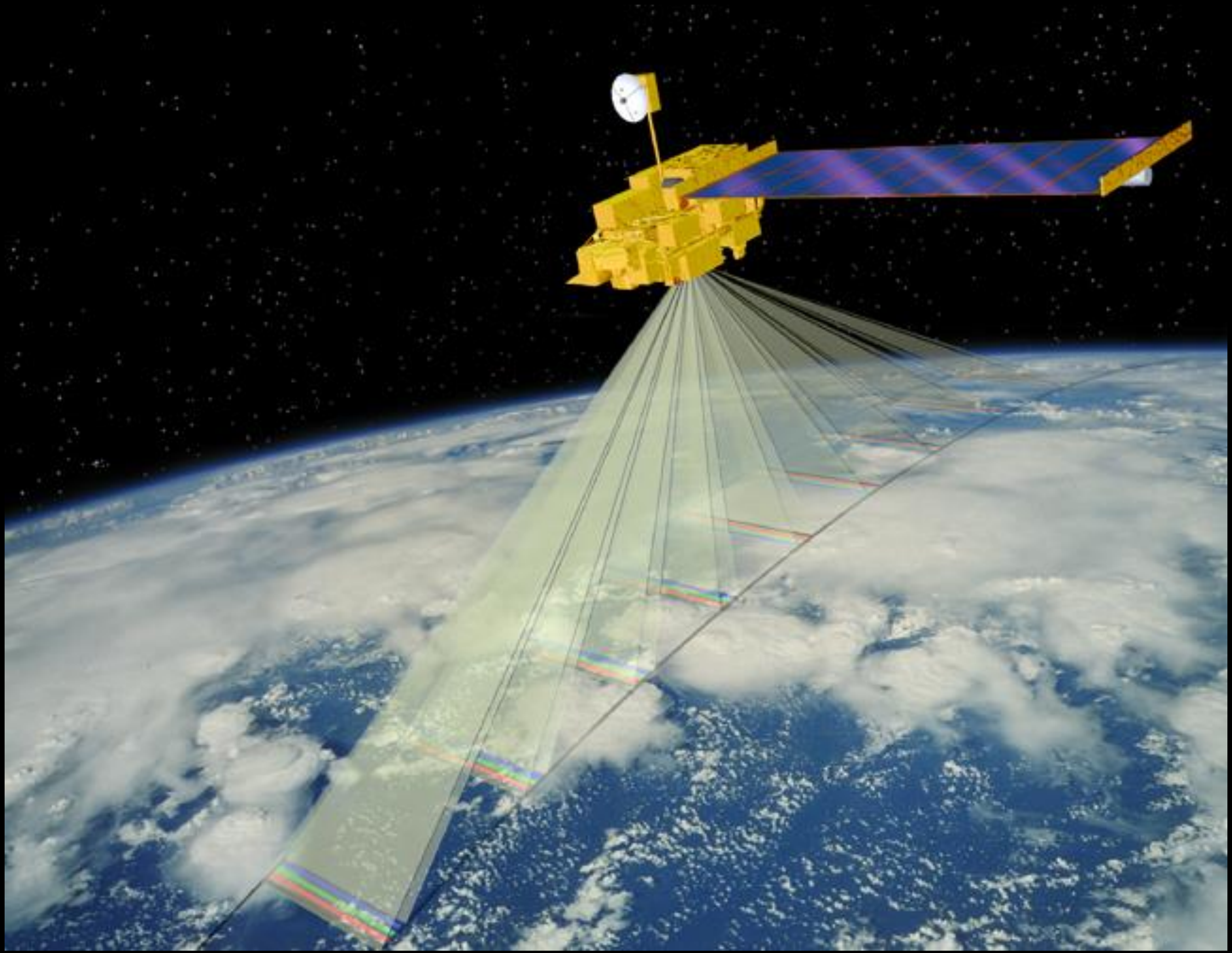
3-D trans-Pacific transport route of the dust storm case. Aerosol vertical curtains: CALIPSO nighttime measurements. Red (blue) lines : backward trajectories from the target region “A” (“B”).

Guo et al. (2017)

Scientific questions

- Which dust source, Taklamakan or Gobi, are more responsible for trans-Pacific transport of dust to North America?
- How often do the trans-Pacific dust transport events occur?

Multi-angle Imaging SpectroRadiometer (MISR)



9 view angles at Earth surface: 70.5º forward to 70.5º backward

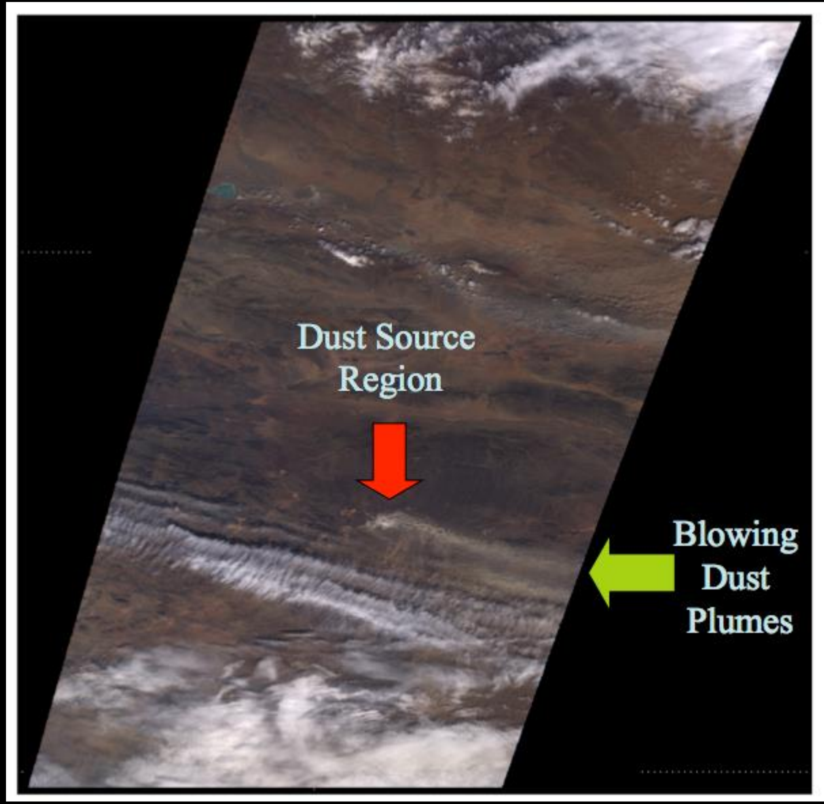
7 minutes to observe each scene at all 9 angles

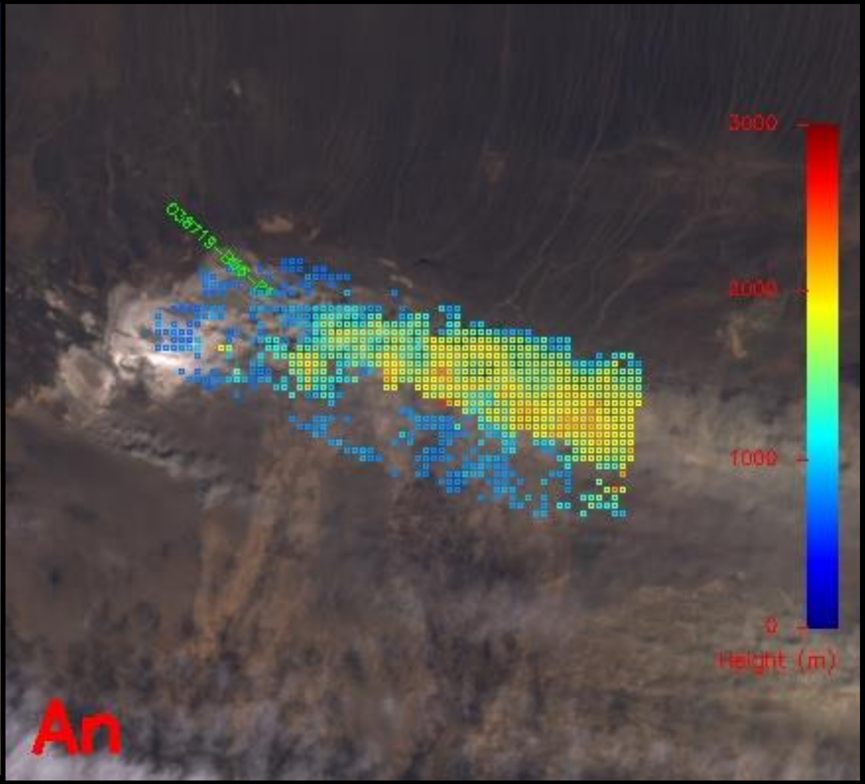
Terra satellite crosses Equator at 10:30 local time: important for Asian dust sources active in the morning

400-km swath: views the study region of East Asian every 5-6 days

MISR Interactive eXplorer (MINX) technique

Juyan Lake Basin in Mongolia, March 30, 2007



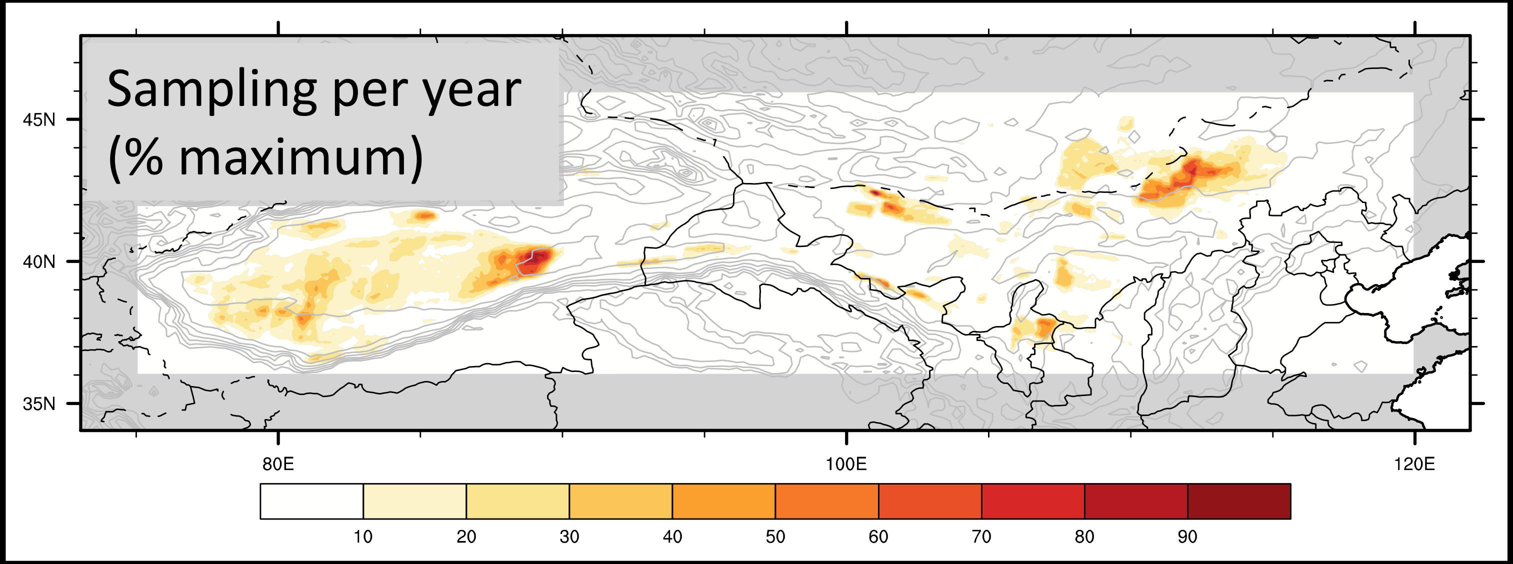


MINX pattern matching technique and stereo retrievals provide:

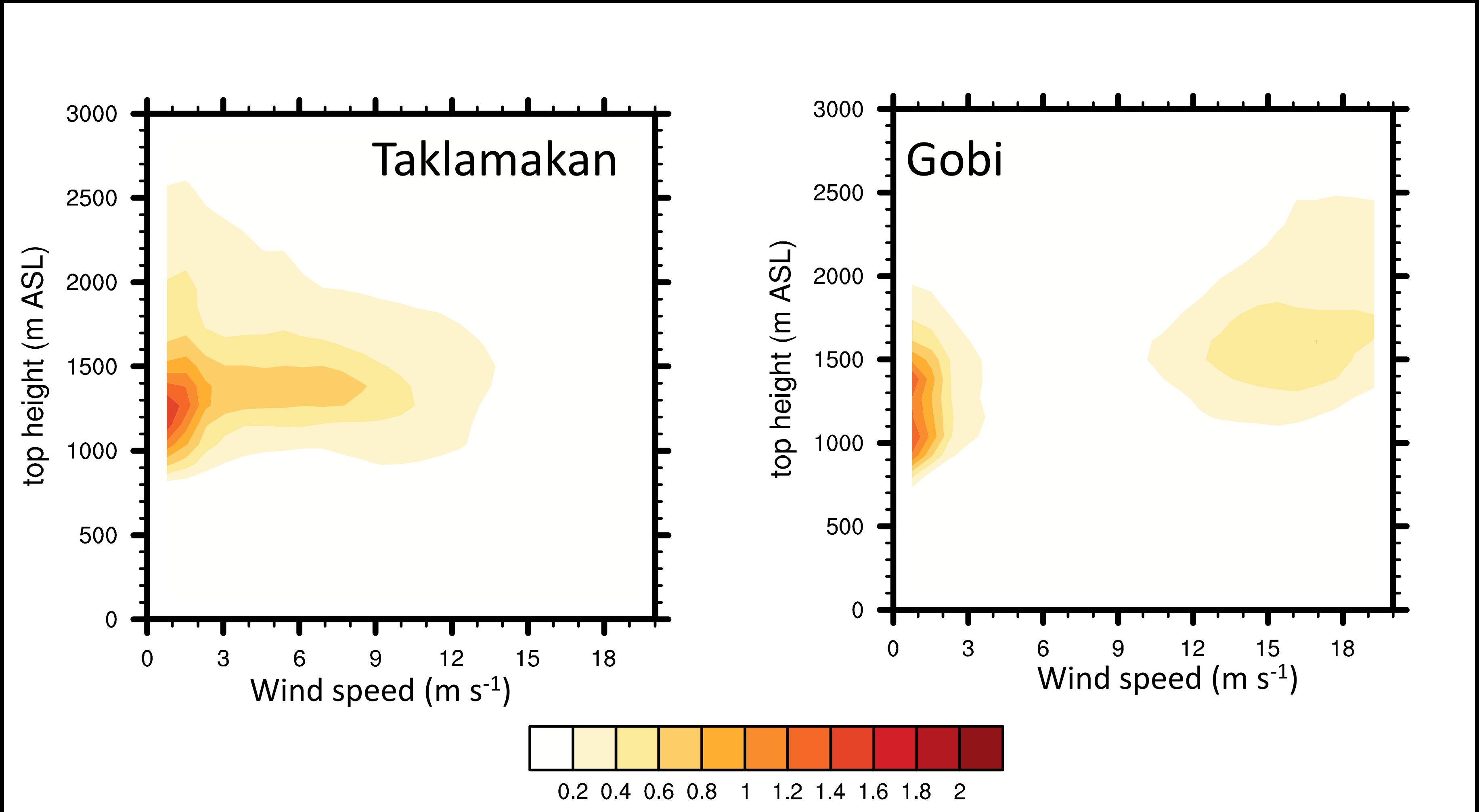
- Plume top heights (~200 m vertical resolution) – 1.1 km spatial resolution
- Associated vector winds (speed and direction) – 1.1 km spatial resolution
- Location of high near surface wind speeds (0.5 m/s uncertainty)

HYSPLIT forward trajectory modeling

- Starting latitude/longitude/height/time: dust plume data from MISR
- Meteorology: NCEP-NCAR reanalysis
- 2251 events, 310290 dust plume data points across central Gobi (2001-2003) and 8945 events, 1086741 dust plume data points across Taklamakan (2001-2011).



Injection height and associated wind speed

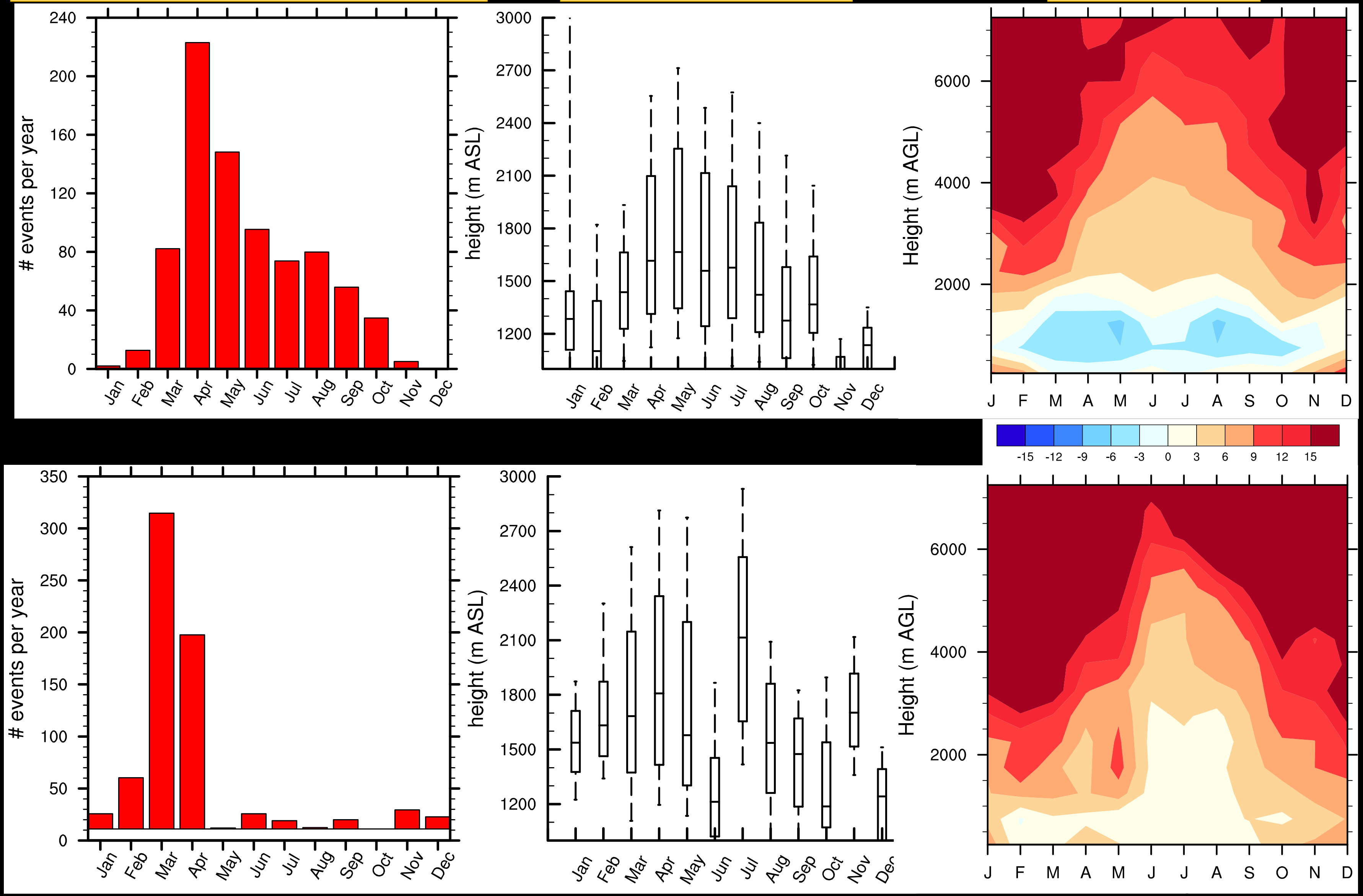


Seasonality in the potential for long-range transport

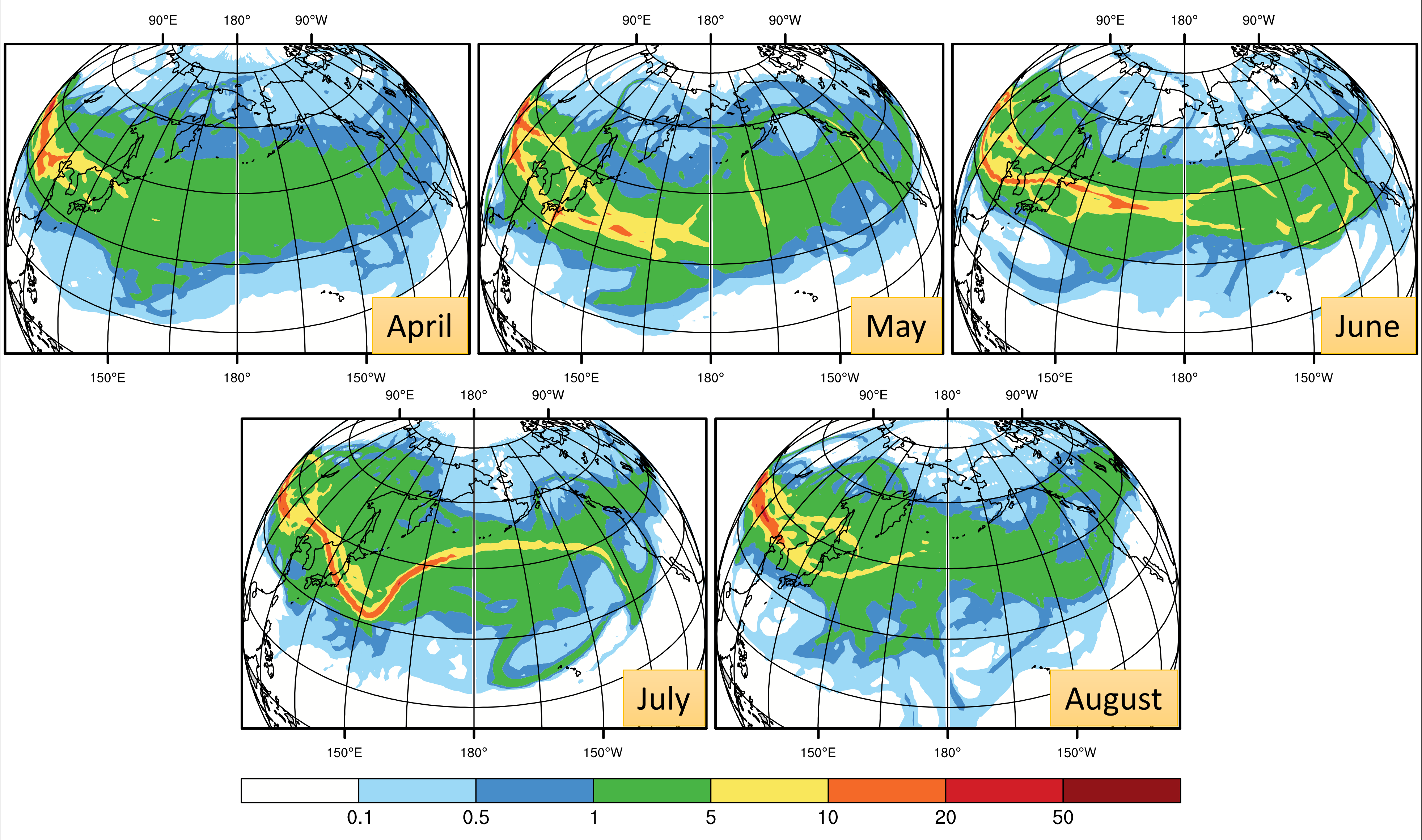
Dust activation occurrence | Injection height | Zonal wind

Taklamakan

Gobi

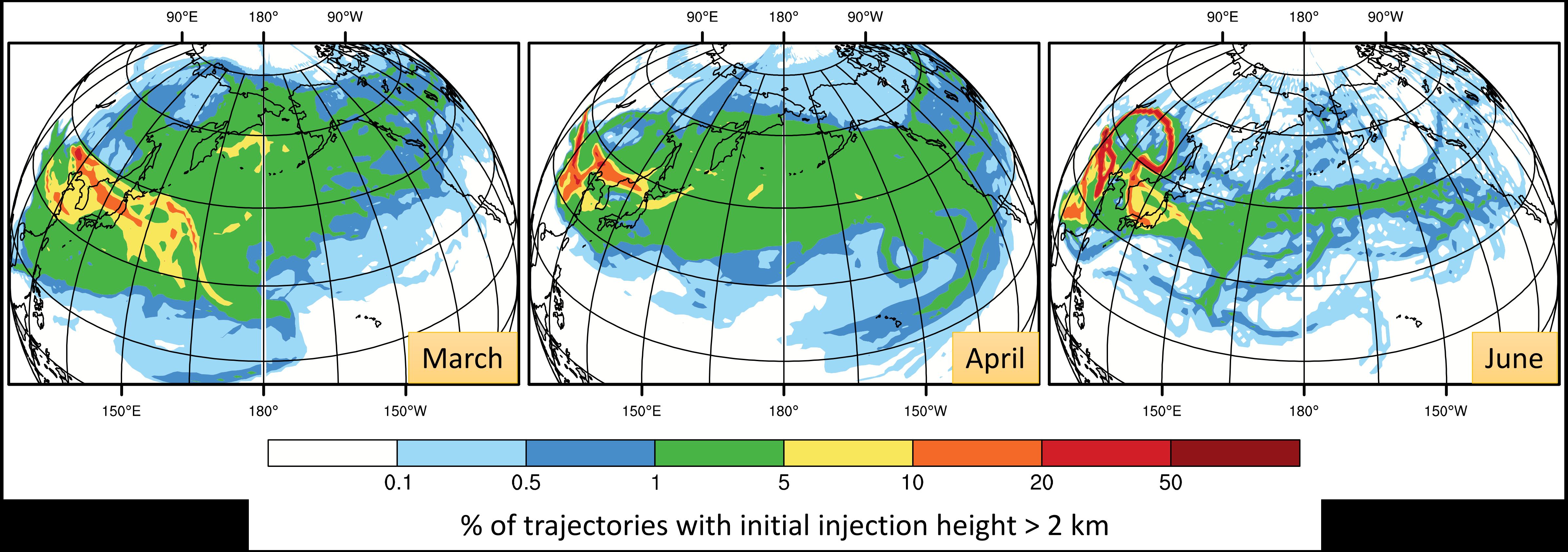


Trajectory passage frequency from Taklamakan

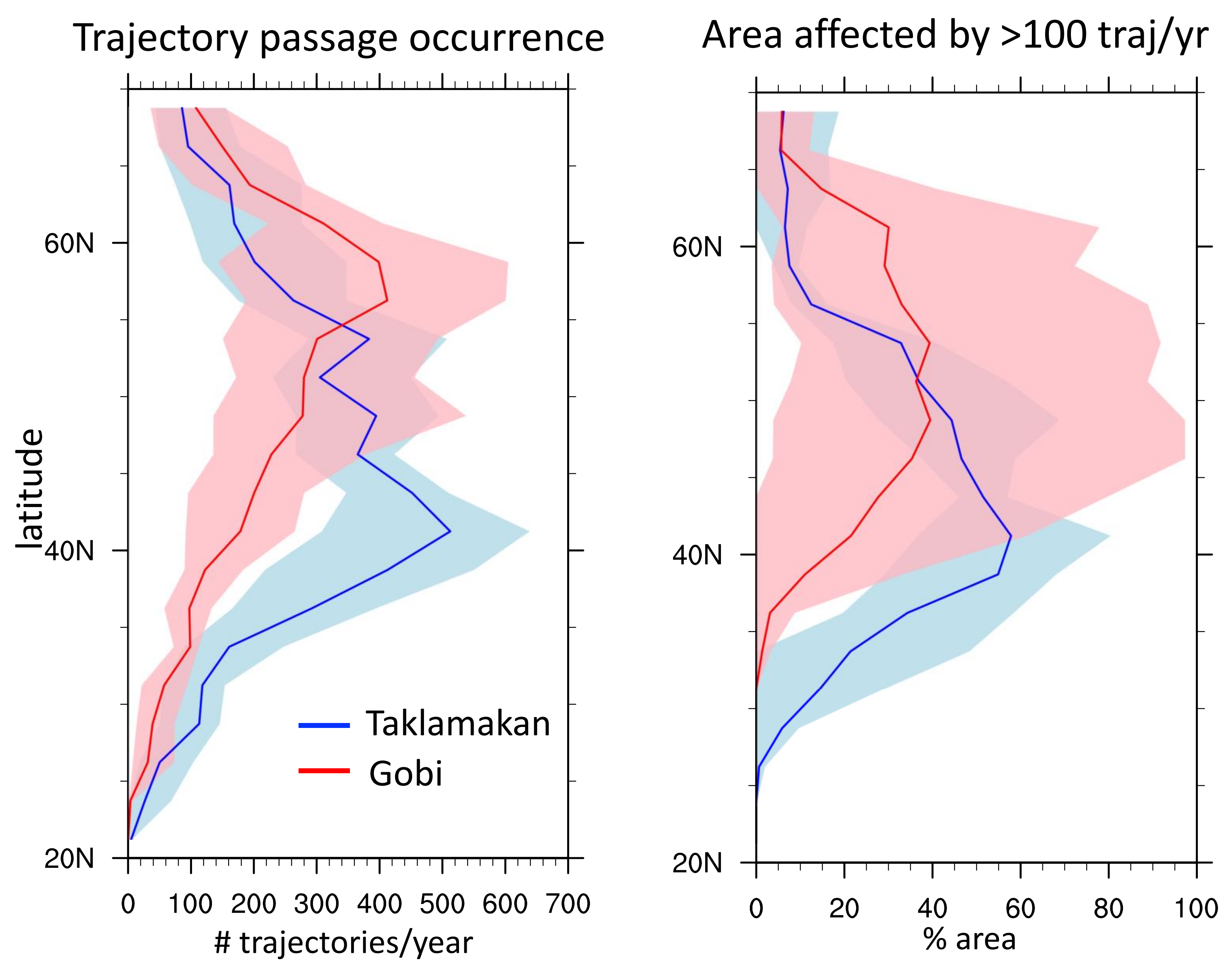


% of trajectories with initial injection height > 2 km

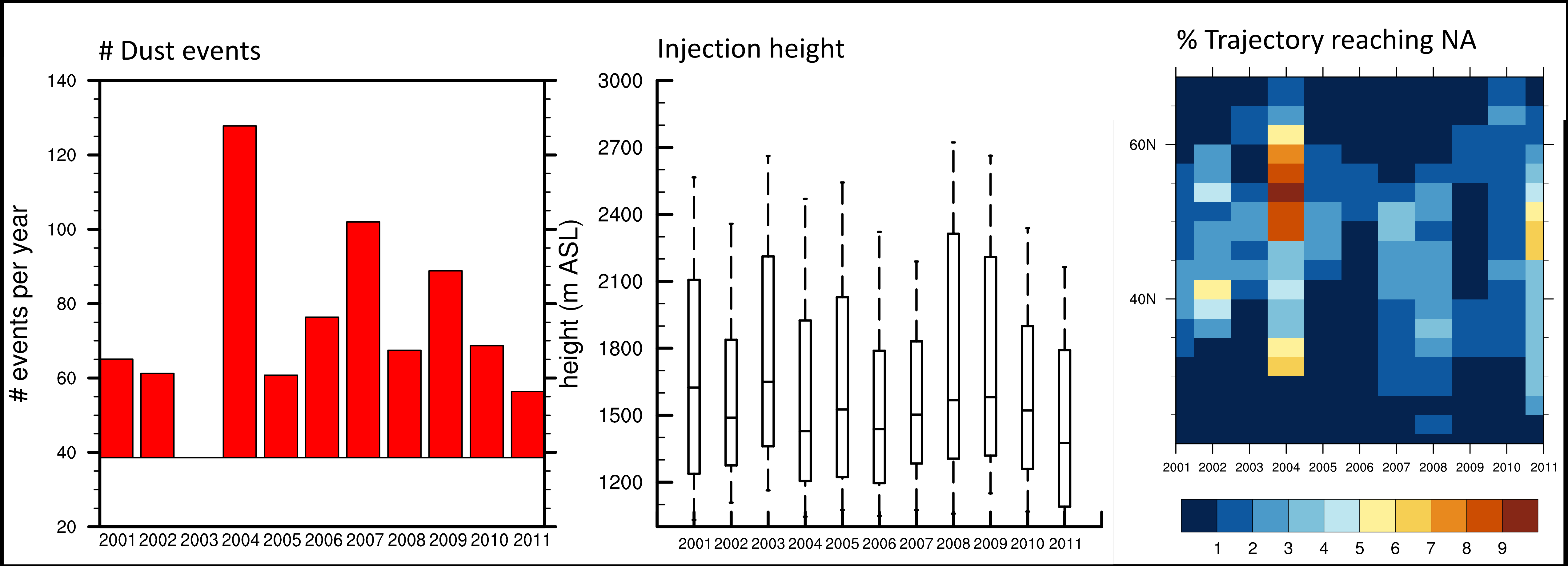
Trajectory passage frequency from Gobi



Influence of Asian dust on North American continent



Interannual variability in dust activation and transport



Summary

- Dust source activities over the Taklamakan and Gobi deserts are examined using MISR plume data, thereby initiating trajectories.
- Despite higher surface elevation across Gobi, Taklamakan dust is more easily uplifted to higher altitudes.
- Gobi dust activation and transport mainly occurs in spring, compared with active dust activation and transport from Taklamakan in both spring and summer.
- Taklamakan dust reach North America more frequently than Gobi dust. Influence of Taklamakan dust maximizes around 40˚N in North America, compared with 50˚N - 60˚N affected by Gobi dust.

Future work

- We hypothesize size (Taklamakan) < size (Gobi) leading to higher frequency of transport to North America from Taklamakan. This hypothesis can be tested in particle size distribution along trajectory from ground and satellite observations.
- Interannual variability in dust activation and transport motivates further observational and modeling studies to investigate the drivers.
- Dust-pollution interaction and potential impacts on aerosol particle morphology, atmospheric chemical composition, regional air quality, and regional climate require further exploration.